

**Antipodal magnetic anomalies on the Moon, contributions from impact induced currents due to positive holes and flexoelectric phenomena and dynamo.** G. Kletetschka<sup>1, 2, 3</sup> F. Freund<sup>2</sup>, P. J. Wasilewski<sup>2</sup> V. Mikula<sup>1,2</sup> and Tomas Kohout<sup>3,4,5</sup>, <sup>1</sup>Department of Physics, Catholic University of America, gunther.kletetschka@gsfc.nasa.gov, Washington DC, USA, <sup>2</sup>GSFC/NASA, Code 691, Greenbelt, MD, USA. <sup>3</sup>Institute of Geology, Academy of Sciences of the Czech Republic, Prague, Czech Republic, <sup>4</sup>Department of Applied Geophysics, Faculty of Science, Charles University in Prague, Prague, Czech Republic, <sup>5</sup>Division of Geophysics, Department of Physical Sciences, University of Helsinki, Helsinki, Finland.

Large impacts on the Moon generate large pressure pulses that penetrate the whole body. Several of these large impacts may have generated antipodal structure-with anomalous magnetic intensity. These regions can be more than a thousand km across, with fields of the order of tens to hundreds of nT. This is the case of Orientale, Imbrium, Serenitatis, Crisium, and Nectaris impact basins [1].

The production of large-scale magnetic fields and associated crustal magnetization due to lunar basin-forming impacts was hypothesized to have an origin in fields external to the impact plasma cloud that are produced by the magnetohydrodynamic interaction of the cloud with ambient magnetic fields and plasmas [2]. During the period of compressed antipodal field amplification, seismic compressional waves from the impact converge at the antipode resulting in transient shock pressures that reach 2 GPa (20 kbar). This can produce conditions for shock magnetic acquisition of the crust antipodal to impact basins.

Various electrical phenomena are generated in rocks when impacted. These include resistivity changes, ground potentials, electromagnetic (EM), and luminous signals. Using low- to medium-velocity impacts to measure electrical signals with microsecond time resolution, it has been observed that when dry gabbro and diorite cores are impacted even at relatively low velocities, >100 m/s, highly mobile charge carriers are generated in a small volume near the impact point [3]. They spread through the rocks, causing a rapid rise in electric potentials, EM, and light emission. As the charge cloud spreads, the rock becomes momentarily conductive.

When a dry granite block is impacted at higher velocity, similar to 1.5 km/s, the propagation of the P and S waves is registered through the transient piezoelectric response of quartz. After the sound waves have passed, the surface of the granite block becomes positively charged, suggesting the same charge carriers as observed during the low-velocity impact experiments, expanding from within the bulk. During the next 2-3 ms the surface potential oscillates, indicating pulses of electrons injected from ground and contact electrodes. The observations are consistent with positive holes, e.g. defect electrons in the O<sub>2</sub>- sublattice, traveling via

the O 2p-dominated valence band of the silicate minerals. Before activation, the positive holes lay dormant in the form of electrically inactive positive hole pairs (PHP), chemically equivalent to peroxy links, O<sub>3</sub>X/(OO)\XO<sub>3</sub>, with X=Si<sup>4+</sup>, Al<sup>3+</sup>, etc. PHPs are introduced into the minerals by way of hydroxyl, O<sub>3</sub>X-OH, which all nominally anhydrous minerals incorporate when crystallizing in H<sub>2</sub>O-laden environments. The fact that positive holes can be activated by impacts, and their attendant sound waves, suggests that they can contribute to the mechanism of generation of antipodal magnetic anomalies on Moon.

Another phenomenon that may contribute to the magnetization on the Moon is flexoelectric activation [4] as a result of pressure wave passing through the material. The static effect includes a bulk and a surface charge contribution. The bulk part is due to the fact that the crystal lattice, which has been nonhomogeneously deformed in accordance with the laws of the theory of elasticity, is not in equilibrium from the point of view of displacements in the unit cell. The displacements that are necessary to reach true equilibrium give rise to a dipole moment of the cell, i.e., to polarization. In addition, the deformation of the surface of a finite sample, whose electrical neutrality in the original state was achieved by compensating free charges, leads to a surface contribution which can be expected to be of the same order of magnitude as the bulk part of the effect.

All of these mechanisms produce magnetic fields that have the potential to magnetize magnetic minerals below their Curie temperature. This creates a basis to use magnetic data from the Moon's rocks to see if they support dynamo related magnetization, where the impact has produced antipodal heat accumulation and caused magnetic acquisition through thermal/chemical variation in the presence of dynamo or if they were magnetized by intense electric currents due to the above described mechanisms.

**References:** [1] Halekas J. S. et al., (2003) *Meteoritics*, 38, 565-578. [2] Hood L. L. and Huang Z. (1991) *JGR*, 96, B6, 9837-9846. [3] Freund F. (2002) *J. Geodyn.* 33 (4-5): 543-570 [4] Fousek et al, (1999) *Materials Letters* 39, 287-291, [5] Kletetschka et al., (2004) *Meteoritics*, 39, 11, 1839-1848.